

LEVEL *II*

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Research Memorandum 72-2

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**VERTICAL PHOTOGRAPHIC COVERAGE OBTAINABLE
WITH VARYING FILM FORMAT, FILM FOOTAGE,
LENS FOCAL LENGTH, ALTITUDE, OVERLAP, AND SIDELAP**

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6 VERTICAL PHOTOGRAPHIC COVERAGE OBTAINABLE WITH VARYING
FILM FORMAT, FILM FOOTAGE, LENS FOCAL LENGTH,
ALTITUDE, OVERLAP, AND SIDELAP.

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VERTICAL PHOTOGRAPHIC COVERAGE OBTAINABLE WITH VARYING
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GENERAL

Two tables are presented that make it possible to obtain an estimate of the linear and areal coverage obtainable on 25 feet of 70mm film using a vertical camera equipped with one of three specified focal length lenses, at altitudes ranging from 500 feet to a maximum of 21,000 feet, with or without overlap on successive exposures, and with or without sidelap between successive runs of the mission.

Table 1 is used to determine the denominator of the photo scale of the imagery. This value is called the Photo Scale Reciprocal and abbreviated to PSR. Table 1 is entered using the row corresponding to the altitude flown and the PSR value taken from the intersection of this row and the column headed by the appropriate lens focal length. For example, if the mission is flown at an altitude of 10,000 feet using a camera with a 6-inch focal length lens, the PSR will be 20,000 and the scale of the imagery will be 1:20,000.

ALTITUDE AND LENS FOCAL LENGTH

Table 1 can be used to determine the mission altitude and/or lens focal length that must be used to obtain imagery of a desired scale. If the desired scale is 1:40,000 (a PSR of 40,000), Table 1 is entered in the body of the table and all places where the entry 40,000 appears are determined. For this example, the entry 40,000 occurs at an altitude of 5,000 feet and a lens focal length of 1 1/2 inches, at an altitude of 10,000 feet and a lens focal length of 3 inches, and at an altitude of 20,000 feet and a lens focal length of 6 inches. That combination of lens focal length and flying altitude judged most desirable can be selected.

OBTAINING THE DESIRED AREAL COVERAGE

PSR is used to enter Table 2. For example, PSR of 6,000 designates the bottom row of the first page of Table 2. Imagery with this PSR acquired without overlap between successive exposures can record 39,434 meters of unique ground distance on 25 feet of 70mm film. If 60% overlap is used between successive exposures, the linear ground distance that can be imaged on 25 feet of 70mm film is 15,773 meters. Areal coverage is given in square meters in Table 2 and is tabled for four different conditions--no overlap and no sidelap, no overlap and 10% sidelap, 60% overlap and no sidelap, and 60% overlap and 10% sidelap. With neither overlap nor sidelap, 13,521,747 square meters of unique ground area can be recorded on 25 feet of 70mm film. With no overlap and 10% sidelap, 12,169,572 square meters of unique ground area can be recorded. With 60% overlap and no sidelap, 5,408,699 square meters of unique ground area can be

imaged. Finally, with 60% overlap and 10% sidelap, 4,867,829 square meters of unique ground area can be imaged. It is apparent that surveillance coverage with 60% overlap and 10% sidelap of 10,000,000 square meters of ground area can not be obtained on 25 feet of 70mm film if the PSR is 6,000. This coverage could be obtained by using about 52 feet of 70mm film, by changing the flight parameters to achieve a PSR of 10,000, or by using 25 feet of 5-inch film or 9 1/2-inch film. The effect of film format upon the amount of ground coverage is not directly given in Table 2 but can be estimated from Table 2 data, using the method described below.

The preceding paragraph referred to the fact that additional terrain coverage could be obtained by using greater amounts of film in the camera. The entries of Table 2 can be multiplied by 2 to give estimates for the coverage possible using 50 feet of film, by 10 to give that obtainable with 250 feet of film, or by X/25 to give estimates of the coverage possible with X feet of film. Conversely, if the altitude, lens focal length, and extent of terrain to be imaged using 70mm film are specified, the amount of film required to accomplish this task can be determined by dividing the number of square meters of terrain area to be imaged by the appropriate Table 2 estimate consistent with the given acquisition conditions stated above. For example, a 70mm camera equipped with a 3-inch lens is to be flown at 500 feet above ground level to obtain areal coverage of 1,201,934 square meters with 60% overlap but with no sidelap. How much 70mm film will be required? The PSR determined from Table 1 for the stated mission conditions is 2,000. When this value is used to enter Table 2, it is found that, for 60% overlap but no sidelap, the coverage obtainable using 25 feet of 70mm film is 600,967 square meters. Therefore,

$$\frac{1,201,934 \text{ (required terrain coverage)}}{600,967 \text{ (coverage with 25 feet of film)}} = 2.$$

Fifty feet of 70mm film will be required to obtain the desired terrain coverage.

FILM FORMAT AND AREAL COVERAGE

It is possible to use Table 2 to obtain an approximate estimate of the coverage obtainable with camera systems of 5-inch format or 9 1/2-inch format. Ignoring the fact that there are fewer inter-exposure strips for the larger formats than for the 70mm film, the linear extent of the terrain covered should be about the same regardless of format. The width of the 5-inch format exposure is 4 1/2 inches while the image width of the 9 1/2-inch format is 9 inches. These widths are 2 and 4 times the width of the 2 1/4-inch image size of the 70mm film format. Therefore, the values given in Table 2 for areal coverage can be used by multiplying them by 2 for the 5-inch format or by 4 for the 9-inch format.

The use of these modified values from Table 2 for the 5-inch and 9 1/2-inch film formats give approximate estimates only. Three representative camera systems are listed below along with a specification of the

number of exposures that each can record on 25 feet of film:

Camera Type	Image Size	Number of Frames on 25 feet of film	Number of Frames times image length
KS-67A	2 1/4x2 1/4	114.71	258.0975 inches
KA-30A	4 1/2x4 1/2	62.5	281.125 inches
KA-20B	9x9	31.41	282.69 inches

Since there are more inches of imagery for the two larger formats it is clear that Table 2 values underestimate the coverage possible with these formats. Though not exact, the tabled estimates--with the use of the appropriate multipliers--will provide a first approximation to the actual values.

GROUND RESOLVED DISTANCE (GRD)

The lens/film resolution (LFR) of a camera system, the Photo Scale Reciprocal (PSR) of the imagery, and the Ground Resolved Distance (GRD) are related as shown in the following formula:

$$\text{GRD (feet)} = \frac{\text{PSR}}{304.8 \text{ LFR (millimeters)}}$$

A study ^{1/} conducted under contract by Minneapolis-Honeywell Regulator Company for Rome Air Development Center provides some data bearing on the values of GRD required in order for interpreters to be able to identify targets of specified type. Figure 190 taken from the referenced report is included here as Figure 1.

In order to identify a small truck such as a jeep (1/4-ton truck), the GRD specified in Figure 190 must not be greater than four feet. If we assume that the LFR of the camera system to be flown is 10 line pairs per millimeter--this conservative estimate of lens/film resolution has been selected deliberately--we can solve for the value of PSR that is necessary to make this target identifiable.

$$4 (304.8) (10) = \text{PSR} \quad \text{or}$$

$$12,192 = \text{PSR.}$$

^{1/} Jennings, Luther B., F.B. Meeker, G.A. Praver and R.N. Cook
(Minneapolis-Honeywell Regulator Company). Ground Resolution Study
Final Report. RADC-TDR-63-224. November 1963

From Table 1 we determine that a value of PSR of this magnitude will be obtained if the mission is flown at 3,000 feet with a camera equipped with a 3-inch focal length lens or at 6,000 feet with a camera equipped with a 6-inch focal length lens.

It is possible to set flight parameters first and then determine what minimum LFR is required to make the identification of specified targets possible. This simple equation relating GRD to PSR and LRD completely ignores many factors that bear on image quality. For example, atmospheric attenuation, light and shadow, signal to noise ratio, and others may be responsible for making the identification of targets difficult if not impossible.

Table 1

PHOTO SCALE RECIPROCALs FOR SELECTED ALTITUDES AND FOCAL LENGTHS

Altitude (feet)	Lens Focal Length		
	1½-inch	3-inch	6-inch
500	4,000	2,000	1,000
1,000	8,000	4,000	2,000
2,000	16,000	8,000	4,000
3,000	24,000	12,000	6,000
4,000	32,000	16,000	8,000
5,000	40,000	20,000	10,000
6,000	48,000	24,000	12,000
7,000	56,000	28,000	14,000
8,000	64,000	32,000	16,000
9,000	72,000	36,000	18,000
10,000	80,000	40,000	20,000

Altitude (feet)	Lens Focal Length		
	1½-inch	3-inch	6-inch
11,000	88,000	44,000	22,000
12,000	96,000	48,000	24,000
13,000	104,000	52,000	26,000
14,000	112,000	56,000	28,000
15,000	120,000	60,000	30,000
16,000	128,000	64,000	32,000
17,000	136,000	68,000	34,000
18,000	144,000	72,000	36,000
19,000	152,000	76,000	38,000
20,000	160,000	80,000	40,000
21,000	168,000	84,000	42,000

Table 2

 LINEAR DISTANCE AND AREAL COVERAGE ON 25 FEET OF 70mm FILM
 WITH A VERTICAL CAMERA AND SPECIFIED PHOTO SCALE RECIPROCALs

Photo Scale Reciprocal	Overlap	Linear Distance (meters)	Areal Coverage (square meters)	
			No Sidelap	10% Sidelap
1,000	None	6,572	375,604	338,044
	60%	2,629	150,242	135,217
2,000	None	13,144	1,502,416	1,352,175
	60%	5,258	600,967	540,870
4,000	None	26,289	6,009,665	5,408,699
	60%	10,516	2,403,866	2,163,480
6,000	None	39,434	13,521,747	12,169,572
	60%	15,773	5,408,699	4,867,829

Table 2
(Continued)

Photo Scale Reciprocal	Overlap	Linear Distance (meters)	Areal Coverage (square meters)	
			No Sidelap	10% Sidelap
8,000	None	52,578	24,038,662	21,634,795
	60%	21,031	9,615,465	8,653,918
10,000	None	65,722	37,560,409	33,804,368
	60%	26,289	15,024,164	13,521,747
12,000	None	78,867	54,086,989	48,678,290
	60%	31,547	21,634,795	19,471,316
14,000	None	92,012	73,618,401	66,256,561
	60%	36,805	29,447,360	26,502,624
16,000	None	105,156	96,154,646	86,539,182
	60%	42,062	38,461,859	34,615,673
18,000	None	118,300	121,695,724	109,526,152
	60%	47,320	48,678,290	43,810,461
20,000	None	131,445	150,241,635	135,217,472
	60%	52,578	60,096,654	54,086,989
22,000	None	144,590	181,792,378	163,613,141
	60%	57,836	72,716,951	65,445,256
24,000	None	157,734	216,347,954	194,713,159
	60%	63,094	86,539,182	77,885,264
26,000	None	170,878	253,908,363	228,517,527
	60%	68,351	101,563,345	91,407,011
28,000	None	184,023	294,473,605	265,026,244
	60%	73,609	117,789,442	106,010,498

Table 2
(Continued)

Photo Scale Reciprocal	Overlap	Linear Distance (meters)	Areal Coverage (square meters)	
			No Sidelap	10% Sidelap
30,000	None	197,168	338,043,679	304,239,311
	60%	78,867	135,217,472	121,695,724
32,000	None	210,312	384,618,586	346,156,727
	60%	84,125	153,847,434	138,462,691
34,000	None	223,456	434,198,325	390,778,493
	60%	89,383	173,679,330	156,311,397
36,000	None	236,601	486,782,897	438,104,608
	60%	94,640	194,713,159	175,241,843
38,000	None	249,746	542,372,302	488,135,072
	60%	99,898	216,948,921	195,254,029
40,000	None	262,890	600,966,540	540,869,886
	60%	105,156	240,386,616	216,347,954
42,000	None	276,034	662,565,610	596,309,049
	60%	110,414	265,026,244	238,523,620
44,000	None	289,179	727,169,513	654,452,562
	60%	115,672	290,867,805	261,781,025
48,000	None	315,468	865,391,818	778,852,636
	60%	126,187	346,156,727	311,541,054
52,000	None	341,757	1,015,633,453	914,070,107
	60%	136,703	406,253,381	365,628,043
56,000	None	368,046	1,177,894,418	1,060,104,977
	60%	147,218	471,157,767	424,041,991

Table 2
(Continued)

Photo Scale Reciprocal	Overlap	Linear Distance (meters)	Areal Coverage (square meters)	
			No Sidelap	10% Sidelap
60,000	None	394,335	1,352,174,715	1,216,957,244
	60%	157,734	540,869,886	486,782,897
64,000	None	420,624	1,538,474,342	1,384,626,908
	60%	168,250	615,389,737	553,850,763
68,000	None	446,913	1,736,793,301	1,563,113,971
	60%	178,765	694,717,320	625,245,588
72,000	None	473,202	1,947,131,590	1,752,418,431
	60%	189,281	778,852,636	700,967,372
76,000	None	499,491	2,169,489,209	1,952,540,288
	60%	199,796	867,795,684	781,016,115
80,000	None	525,780	2,403,866,160	2,163,479,544
	60%	210,312	961,546,464	865,391,818
84,000	None	552,069	2,650,262,441	2,385,236,197
	60%	220,828	1,060,104,977	954,094,479
88,000	None	578,358	2,908,678,054	2,617,810,248
	60%	231,343	1,163,471,221	1,047,124,099
96,000	None	630,936	3,461,567,270	3,115,410,543
	60%	252,374	1,384,626,908	1,246,164,217
104,000	None	683,514	4,062,533,810	3,656,280,429
	60%	273,406	1,625,013,524	1,462,512,172
112,000	None	736,092	4,711,577,674	4,240,419,906
	60%	294,437	1,884,631,069	1,696,167,962

Table 2
(Continued)

Photo Scale Reciprocal	Overlap	Linear Distance (meters)	Areal Coverage (square meters)	
			No Sidelap	10% Sidelap
120,000	None	788,670	5,408,698,860	4,867,828,974
	60%	315,468	2,163,479,544	1,947,131,590
128,000	None	841,248	6,153,897,370	5,538,507,633
	60%	336,499	2,461,558,948	2,215,403,053
136,000	None	893,826	6,947,173,202	6,252,455,882
	60%	357,530	2,778,869,281	2,500,982,353
144,000	None	946,404	7,788,526,358	7,009,673,723
	60%	378,562	3,115,410,543	2,803,869,489
152,000	None	998,982	8,677,956,838	7,810,161,154
	60%	399,593	3,471,182,735	3,124,064,462
160,000	None	1,051,560	9,615,464,640	8,653,918,176
	60%	420,624	3,846,185,856	3,461,567,270
168,000	None	1,104,138	10,601,049,766	9,540,944,789
	60%	441,655	4,240,419,906	3,816,377,916

GROUND RESOLUTION LEVELS

TARGET TYPE		1-2 FEET	2-4 FEET	4-8 FEET	8-16 FEET	16-32 FEET	32-64 FEET
AIRCRAFT	Utility A/C (C-54) (L-20)	C-54 L-20	C-54 L-20	C-54 L-20	C-54 Utility A/C	Utility A/C	?
	Fighter A/C (F-101)	F-101	F-101	F-101	Fighter	A/C	?
	Bomber A/C (B-57) (B-52)	B-57 B-52	B-57 B-52	B-57 B-52	Bomber B-52	A/C B-52	?
	Helicopters (Small and Medium)	Sm or Med Helicopter	Sm or Med Helicopter	Helicopter	-	-	-
VEHICLES	Road Grader	Road Grader	Road Grader	Road Grader	Heavy Equip	Vehicle	?
	Bull Dozer	Bull Dozer	Bull Dozer	Bull Dozer	Heavy Equip	Vehicle	?
	Semi & Enclosed Trailer	Semi & Encl Trailer	Semi & Encl Trailer	Semi & Encl Trailer	Large Truck	Vehicle	?
	Tank Truck	Tank Truck	Tank Truck	Tank Truck	Vehicle	-	-
	2½-Ton Truck	2½-Ton Truck	2½-Ton Truck	2½-Ton Truck	Large Truck	-	-
	Jeep	Jeep	Jeep	Small Truck	Vehicle	-	-
	Railroad Vehicle	Flatcar, Boxcar, etc.	Flatcar, Boxcar, etc.	Flatcar, Boxcar, etc.	Railroad Vehicle	Railroad Vehicle	?
	Tank (Light, Medium, Heavy)	Lt, Med, or Hvy Tank	Lt, Med, or Hvy Tank	Tank	Tank	Tank	?

Symbol Meaning: (*) = Under Some Conditions; (-) = No Identification Possible; (?) = Unknown

Figure 1. Target Identifiability at Various Levels of Ground Resolution. From Figure 190, page 235, Jennings et al, Ground Resolution Study Final Report, RADC-TDR-63-224, November 1963.

GROUND RESOLUTION LEVELS

TARGET TYPE	1-2 FEET	2-4 FEET	4-8 FEET	8-16 FEET	16-32 FEET	32-64 FEET
WEAPONS	Man Carried Weapon	-	-	-	-	-
	Vehicle Mounted Weapon 105mm & 155mm	105mm or 155mm Weapon	Vehicle Mounted Wesp	-	-	-
	Towed Weapon	8" Gun	Towed Weapon	-	-	-
	Howitzer	8" Howitzer	Towed Weapon	Towed Weapon	-	-
	Missile (Gnd Launch)	Msl Gnd Lnc	Msl Gnd Lnc	-	-	-
	(Air Launch)	Msl Air Lnc	Msl Air Lnc	-	-	-
MISCELLANEOUS	Tent (10 Man & Hosp)	Tent	Tent	Tent	-	-
	Jet Engine Test Area	Jet Engine Test Area	Jet Engine Test Area	Complex	Complex	-
	Fuel Dump	Fuel Dump	Fuel Dump	Fuel Dump	Fuel Dump	Fuel Dump
	Airfield	Airfield	Airfield	Airfield	Airfield	Airfield
	Road (Improved)	Road	Road	Road	Road	?
	Troops	Troops*	-	-	-	-
	Railroad Tracks	RR Tracks	RR Tracks	-	-	-
	Bridge	Bridge	Bridge	Bridge	Bridge	?
	Dam	Dam	Dam	Dam	Dam	Dam

Symbol Meaning: (*) = Under Some Conditions; (-) = No Identification Possible; (?) = Unknown

Figure 1. Target Identifiability at Various Levels of Ground Resolution. From Figure 190, page 235, (Cont'd) Jennings et al, Ground Resolution Study Final Report, RADC-TDR-63-224, November 1963.